The Contribution of Scientific and Historical Data to the Conservation and Management of the Island of Lokrum Marine Area

Doprinos znanstvenih i povijesnih podataka očuvanju i upravljanju podmorjem otoka Lokruma

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Summary

In order to collect relevant data on the status of habitats and species which could be applied in the management of the Lokrum marine area, the paper shows the stages in the research of this area. Reliable published data, travelogues and scientific papers, were analysed and taken into consideration to propose the guidelines for managing primarily the marine area of the Natura 2000 site Lokrum.

KEY WORDS

Lokrum
Adriatic Sea
management of protected areas
historical data

Sažetak

U svrhu prikupljanja mjerodavnih podataka o statusu staništa i vrsta koji bi se mogli primjenjivati u upravljanju podmorjem otoka Lokruma, pregledno je prikazan slijed istraživanja ovoga područja. Analizirani su dostupni objavljeni podaci – putopisi i znanstveni radovi, te su na temelju njih predložene smjernice za upravljanje prvenstveno morskim dijelom ekološke mreže Lokruma.

KLJUČNE RIJEČI

Lokrum
Jadransko more
upravljanje zaštićenim područjima
povijesni podaci

1. INTRODUCTION / *Uvod*

The island of Lokrum, a special nature reserve of forest vegetation and an area of the Natura 2000 ecological network [3,5] is located in the close vicinity of the city of Dubrovnik and is included in the UNESCO World Heritage List as an integral part of the Historic City Center of Dubrovnik with its city walls and fortresses and the city harbor [6]. Moreover, the Lokrum area has been listed as a cultural property in the Immovable cultural monuments list and following the Decree on the protection of the historic city center of Dubrovnik with its close surroundings, the Lokrum area has become part of the "A" zone "with a complete protection of historical structures" [59].

Lokrum is situated in the southern part of Croatia, 600 m off the coast. It is 1.5 km long with a surface of 72 ha (Figure 1). Notwithstanding this, there are numerous habitat types on the island ranging from forest and cultivated areas to sea rocks and speleological objects – on the land and in the marine area, as well as reefs and *Posidonia* beds (*Posidonion oceanicae*). In view of specific characteristics of vegetation, which includes all natural development stages of plant communities in the Mediterranean region as well as a large number of plant species on a small area, Lokrum, as early as in 1948, is protected as a special forest vegetation reserve [61]. It is one of the three oldest protected areas of nature in Croatia out of existing 408 national protected areas covering 12.22% of the land territory and 1,94% of the territorial sea of The Republic of Croatia [82]. In accordance with the Regulation on the ecological network from 2013 [2,4] Lokrum is an integral part of the Natura 2000 ecological network which covers 36.73% of the Croatian land territory and 15,42% of its coastal marine territory [82]. There are eight protected habitat types of European importance on the island and its marine area which extends approximately 150 m off the coast (Table 1).

The Nature Protection Act [3,5] requires management of protected areas and the areas of the ecological network by public institutions that protect, conserve and promote the protected area with the final aim of protecting and conserving the very nature, uninterrupted development of natural processes and sustainable use of natural resources. Public institutions both supervise the implementation of nature protection measures in the area they are managing and participate in collecting data to monitor nature preservation (monitoring). The Government of Croatia has to define conservation objectives for each area of the ecological network (Natura 2000 site) and implement the necessary conservation measures in order to achieve these

objectives. This paper will therefore be used as background information for setting up the conservation objectives and defining conservation measures for effective management of Lokrum Natura 2000 site.

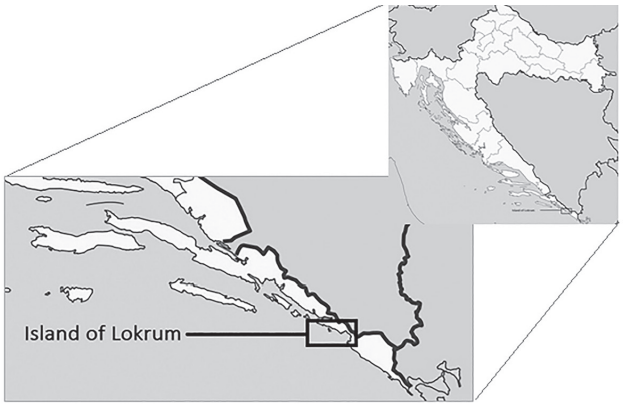
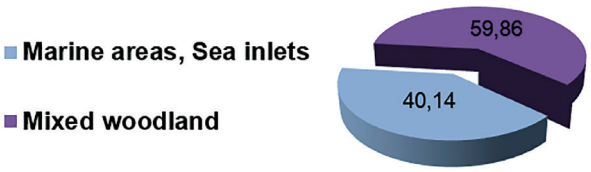


Figure 1 Geographical position of the island of Lokrum

Slika 1. Geografski položaj otoka Lokruma



Source: www.bioportal.hr/gis

Figure 2 Surface of land and marine habitat types of the Natura 2000 site Lokrum [82]

Slika 2. Prikaz površina kopnenih i morskih stanišnih tipova Natura 2000 područja Lokrum [82]

Despite the fact that the natural and cultural values of the island were recognized a long time ago, that it was legally protected on different levels, nationally and internationally, as well as the natural history tradition of the area and the permanent scientific and professional work on the island during the 20th century, there is a lack of reliable data on the status of habitats and species which could be applied in its management. To be more precise, in the last forty years no systematic research has been carried out on the island, and it is precisely in this period that significant changes in nature, both globally and locally have occurred. This can pose a serious challenge in defining conservation objectives, but at the same time this should not prevent implementation of the necessary measures to safeguard the protected species and habitats. It is therefore a priority to establish good baseline for monitoring of the status of protected species and habitat types, which can only be done with systematic research efforts.

In addition to this, efficient management and protection of the island is difficult to achieve due to inadequate legislation not allowing the Public Institution Lokrum Reserve to manage the marine area of the ecological network. The management of the land area of the ecological network is clearly defined and is being implemented, while the management of the marine area covering more than 40% of Lokrum Natura 2000 site (Figure 2) is awaiting a decision of the Government of Croatia which will define the management authorities for marine Natura 2000 site.

The purpose of this paper is to analyse reliable published data – travelogues and scientific papers and, taking into consideration the results, to suggest the guidelines for managing primarily the marine area of the ecological network site Lokrum.

2. DOCUMENTS AND STUDIES ON THE ISLAND OF LOKRUM / *Dokumenti i studije o otoku Lokrumu*

Natural values of Lokrum as well as Dubrovnik and its surroundings have been the subject of a number of natural history studies and a destination for world travellers and travel writers since 19th century [54,1,48,50]. The data published in scientific papers and travelogues, especially in those from the end of 19th and the beginning of the 20th century are a valuable source of information about the natural values of the island so they make it possible to monitor the changes in biodiversity. These studies also provide data on the landscape, complete cultural heritage and different perceptions of Lokrum at that time.

Flora of the island has always attracted visitors and inspired naturalists who recognized and described its value in the 19th century [80,1], while studies of the terrestrial fauna on the island itself were not so representative [30]. A special motif of Lokrum is a submerged sea cave, known as the Dead Sea (*Mare Morto*), whose value was also recognized and described in the 19th century. The chemical properties of the Dead Sea were analysed and described at that time [54], while in 1892 Habsburg Crown Princess Stephanie [50] wrote about some geomorphological characteristics of the Dead Sea in her travelogue Lacroma. She

Table 1 Site of Community importance (SCI) Lokrum (According to the excerpt from the Regulation on the ecological network, appendix III, part 2) [2,4]

Tablica 1. Područje očuvanja značajno za vrste i stanišne tipove (POVS) Lokrum (prema izvatku iz Uredbe o ekološkoj mreži, prilog III., dio 2.) [2,4]

Area identification number	Area	Habitat type	Habitat type code
HR 4000017	Lokrum	Posidonia beds (*Posidonion oceanicae*)	1120*
		Reefs	1170
		Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp.	1240
		Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	6220*
		Calcareous rocky slopes with chasmophytic vegetation	8210
		Submerged or partially submerged sea caves	8330
		Quercus ilex and *Quercus rotundifolia* forests	9340
		Mediterranean pine forests with endemic Mesogean pines	9540

* indicates a priority habitat

described Lokrum comparing it with Italian and Greek tourist destinations from that time, wishing to attract future visitors by emphasizing its special value. Today, the Dead Sea with its cave and canal connecting it with the open sea, is part of the ecological network and is protected as a habitat type of submerged or partially submerged sea cave [2,4].

At the same time, Crown Prince Rudolf, the princess's husband, studied birds, thus contributed significantly to the knowledge of Lokrum ornitofauna [48]. Baldo Kosić, a naturalist and curator of the Dubrovnik Patriotic Museum (*Museo Patrio*), described the birds recorded on Lokrum [49]. Due to the great importance of the island regarding its ornitofauna, in 1961 the Biological Institute JAZU in Dubrovnik founded the Ornithological station and the bird ringing and monitoring centre was also active for a long period on the island. Ivo Tutman, an ornithologist from Dubrovnik largely contributed to the activities of the Center and data publishing [76].

Kolombatović in 1904 [47], in his research on Dalmatian vertebrates, described a museum object, a specimen of the fish species *Julis turcica*, Risso, nowadays known as *Thalassoma pavo* (Linnaeus, 1758) originating from the Lokrum area. Spiridon Brusina, a naturalist and museum expert, described the fauna of Lokrum in a large number of his scientific papers [19,20,21,22,23,24]. In 1907 [23] he described a rarely recorded sea snail species, the violet sea-snail *Janthina janthina* (Linnaeus, 1758) found on Lokrum in 1868 and his collaboration with Dubrovnik Franciscan and naturalist Kuzmić, who was engaged in researching the malacofauna of Lokrum [53]. The described specimens of violet sea-snails continue to be an integral part of the malacological collection at the Natural History Museum in Zagreb [42]. In the same study, Brusina [23] emphasized the need to establish a zoological station in the vicinity of Dubrovnik.

Professor Tomo Gamulin, a distinguished scientist who exceptionally contributed to the 20th century Croatian marine biology, in 1956 advocated a new scientific-cultural institution on Lokrum as it was "the most suitable location regarding the scientific issues (botanic and marine)" so in 1958, the Biological Institute JAZU and Dubrovnik Natural History Museum started their work on the island [52].

Extraordinary ecological values of Lokrum made the island suitable to hold field classes for biology students from the Faculty of Science of the University of Zagreb [73,78]. After the 1979 earthquake in Dubrovnik and the resulting damage on the Monastery complex, it wasn't possible to continue with the courses. Later on, professor Milan Meštrov encouraged the restoration of the Benedictine monastery in order to establish a scientific-education station of the University of Zagreb [58]. However, during the Croatian War of Independence the Monastery was ruined even more and the project was abandoned. The necessity of establishing an interdisciplinary biology station on Lokrum which would provide for long-term ecological and biogeographical research projects on the southern Adriatic islands was emphasized in later studies [33,72].

Lokrum has attracted visitors since the very beginning of tourism in Dubrovnik thanks to its extraordinary natural and cultural values, its appropriate position and good climate. Dragutin Hirc, as early as in 1905, wrote about visitors from Italy, Germany, Belgium, Russia, England, France and America in his Physical Geography of Croatia [40]. The interest for the island has remained unchanged. The founder of the unique tourist guides at the end of the 19th century, Baedeker [8,9,10], discussed the possibilities and conditions of visiting Lokrum in his guidebooks, which confirms the fact that visitors have an important role in this area, therefore the use of the island should be planned carefully, taking a long-term view.

During the 20th century, research of flora [38,39] and fauna [70,25,63] continued. Moreover, the Lokrum marine area was sporadically researched [69]. The ecological studies of the marine area [14] as well as the study of phytobenthos of the coastal part of the island [74] were conducted during the second part of the 20th century. The flora and fauna of Lokrum benthic biocenosis is still very representative of the southern Adriatic area and thus relatively well preserved; as many as 734 taxa found up to a 100 meter depth were described, 281 of which were plant and 453 were animal taxa [75]. The molluscs collected in this area earlier were also described [42], and there was a growing interest to obtain the information on sea currents and the oceanographic properties of the sea in this area [81,65]. Long term comprehensive research of the southern Adriatic planktonic communities had been conducted for a couple of decades. It was carried out in the close vicinity of Lokrum, in the Lokrum canal and especially at permanent research stations to the south of the island [15,41,34,56,55,18,35,44,11,12,13,36].

During the described research, some planktonic species new to science were recorded and described, among which it is interesting that tunicate *Brooksia lacromae* Garić & Batistić, 2016 (Tunicata, Thallicea) was named after Lokrum, emphasizing the importance of the island for Adriatic planktonologists [36]. Recent studies include the disappearance and vulnerability of certain species in this area [43], as well as new records of the species whose appearance in the Adriatic sea has rarely been reported [28]. Allochthonous species, one of the main threats to biodiversity, have been studied as well as their interaction with autochthonous species [64,31,62,57]. There have also been studies on other anthropogenic threats to the Lokrum area, such as the influence of the increasing number of anchoring vessels in front of the island [32,27]. The Dead Sea area with its diatom communities [26] and ichthyofauna [29] have also been the subject of research. The studies emphasize the necessity to preserve important habitats, such as *Posidonia oceanica* beds [17]. Students have had the opportunity to participate in the research of the Lokrum marine area [67,37], as a continuation of good practice relevant to collect the information of this area.

3. THE IMPLEMENTATION OF DOCUMENTS AND RESEARCH RESULTS IN PLANNING THE MANAGEMENT OF THE AREA / *Primjena zapisa i rezultata istraživanja u planiranju upravljanja područjem*

Nature protection should be mainly based on the data and guidelines obtained in scientific and applied studies [71]. However, the lack of reliable data is often a limiting factor in managing both the protected areas and the ecological network areas. A significant contribution to the knowledge of an area could also be historical data from travelogues or some earlier research studies by naturalists. Although some general guidelines and the measures of preserving and protecting certain habitat types are already known, scientific papers and

the obtained results from specific areas could serve as a base for improving the existing and developing new management guidelines. The published travelogues and scientific research, as an important source of information, can be applied in defining the guidelines for the management plans and other documents used by nature protection institutions and are of an extraordinary importance for monitoring of changes in nature.

This research notes 72 papers and travelogues on Lokrum area with emphasis on its coastal and marine area. In order to stress the integrity of marine and coastal area of this island with unique natural history tradition, the papers connected to the institutional researches and educational programmes were also analysed. Five studies dating from the 19th century, eleven studies from the 20th century and eleven studies from the 21st century were analysed thoroughly (Table 2). Important activities, guidelines, suggestions and threats described in the papers are specifically recorded and they are, for the purpose of this study, represented as management guidelines. In order to reach a decision on the most convenient activities, the management guidelines are grouped into appropriate types of activity in accordance with the Management planning guidelines for protected areas and/or the ecological network sites [60].

By recognizing and analysing the activities, measures, goals and recommendations from the scientific papers and travelogues, the management guidelines, applicable to the Lokrum area and compatible with the practice of developing plans for managing protected areas and ecological network sites, are defined (Table 2). This paper defines seven management activities (research, monitoring, education, informing, regulation, active management, cooperation) out of twelve types of management activities usually used in management plans of protected areas [60].

Preserving natural values is explained in 18 guidelines that are primarily related to research, monitoring and active management. Thus, with an insight into Loebisch's paper, 1876 [54], a guideline on the habitat type of submerged or partially submerged sea caves is defined, while a guideline on bird monitoring is defined by using Rudolf's ornithological notes from 1887 [48].

A necessity of monitoring *Posidonia oceanica* beds in the Lokrum marine area is specially accentuated in the Protocol on *Posidonia oceanica* monitoring [68] which is well illustrated in the papers pointing out the threats of allochthonous red alga *Womersleyella setacea* (Hollenberg) R.E. Norris, 1992 [62] and green alga *Caulerpa racemosa* (Forsskål) J. Agardh, 1873 [64,31]. In response to these pressures related to scientific research, the appropriate guidelines are pointed in the paper (Table 2). The guidelines on research and monitoring of the complete benthic community with a special emphasis on the habitat type reefs have also been defined.

It is necessary to collect as much relevant data as possible to manage and plan the monitoring of the target habitat types and to set the appropriate conservation objectives that will be the basis for effective conservation measures.

An example of the lack of data on the distribution and state of *Posidonia* meadows in the Adriatic Sea is given in the Monitoring protocol for *Posidonia oceanica* beds [68], which stresses that scientific research is inevitable in order to collect basic data required to begin the monitoring of species.

The issue of marine debris was mentioned in 2016 when the specimen of the sea-snail *Janthina janthina* was described [28]. This sea snail was also described in 1907 [23], but it was found among the seaweed remains on the coast of Lokrum. These studies have shown the need to establish a natural history collection for the purpose of facilitating scientific research and education as well as undertaking marine debris removal from the Lokrum marine and coastal area. These guidelines also contribute to the development of interpretation and education.

Despite the lack of scientific research relating to marine debris, it is evident that the island is threatened by it, especially during the winter due to the island's exposure to the open sea and strong currents. The scientific paper from 2017 [77] states the possibility of allochthonous marine organisms colonizing the open sea in the southern Adriatic through floating marine debris. Regarding the geographic position of Lokrum, its vicinity to the land and its exposure to the open sea, it is necessary to systematically collect scientific and professional papers relating to the south Adriatic and the Mediterranean sea, the results of which show the threats that could affect the Lokrum marine area.

Regarding marine traffic pressures, the *Posidonia* meadow was damaged in 2004 by anchors dredging the sea bed, during two cruise ships collision at anchorage in the Lokrum canal [32]. The water-supply system suffered serious material damage and the fire protection measures on the island were threatened. Another research of the Lokrum marine area recorded that both, the water column and the sediment from the sea bottom, were contaminated by antifouling boat paint and heavy metals from ships [27]. Based on the given facts, there is a need for a scientific research on the marine pollution caused by ships. The need to regulate anchoring in the *Posidonia oceanica* beds as well as in the buffer zone has been suggested. The recommended defined guidelines are based on the conclusions from scientific papers in the field of ecology and natural history. However, one also has to take into consideration that the Lokrum area is a protected cultural value on the World Heritage List so the management guidelines should include the cultural and historical part of the city as well. UNESCO documents the need to limit the number of ships, vessels and yachts passing and anchoring in the area between the Historic City Centre and Lokrum except for boats transporting visitors to Lokrum [7].

Travelogues confirm the fact that world travellers have been interested in Lokrum since the 19th century. Taking into consideration Stephanie's travelogue [50], Baedeker Guides [8,9,10], Petermann's [66] and Hirc's travelogues [40] the guidelines for creating and implementing educational programs for different groups of visitors and especially programs for the education of tourist guides have been defined and serve as a base for a higher quality visitor management. Coastal and marine motifs such as the Dead Sea, Natural Arc, sea caves, sea rocks and cliffs are confirmed to be of special value. These motifs represent a special part of the landscape and are not only a tourist attraction but also an integral part of the habitat types of the ecological network. In addition to the already mentioned marine habitat types, it is necessary to underline the importance of habitat types vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp. whose endemic and rare community *Limonietum anfracti* Ilijanić & Hećimović 1982 was described on the islands of the southern Adriatic including Lokrum [38].

At the end of the 19th century visits to the island were limited and controlled by a special regulation and visits were not free of charge [8]. From the beginning of 20th century guided visits to the monastery have been allowed. As sustainable development is one of the protected area goals, it is essential to understand all aspects of visiting the island and the risks incurred. Therefore, it is crucial to conduct researches as the base of visitor management.

Although a need for establishing a zoological station was noted by Brusina as early as in 1907 [23], the institutionalized scientific work on Lokrum began with the activities of the Biological Institute JAZU and Natural History Museum in 1958 [52], but their scientific work was gradually stopped. Yet, the idea and need for a scientific-research centre continued to be present and was supported by a number of scientists from different fields [79,58,45,33,72].

Apart from scientific-research work, field courses were held for biology students who stayed on the island. Tavčar and Šegulja in 1989 [73] stressed the importance of holding field courses on Lokrum as well as on other sites in the wider territory of Dubrovnik – the islands of Mrkan and Bobara, the Srđ hill and Vjetrenica cave. The collections from the Dubrovnik Natural History Museum weren't available to the public at that time, so Kršinić published paper suggesting the need for establishing a new museum which should exhibit the existing collections systematically presented, as well as establishing new collections which should be presented in line with the ecological principles covering the themes of the protected areas of Dubrovnik among which a special place should be reserved for the special reserve Lokrum [51].

Table 2 Guidelines on managing the Lokrum marine area based on the analysed scientific papers in chronological order (management guidelines – created on the basis of the described activities, measures, goals, recommendations and threats mentioned in the analysed papers; type of activity – defined for each management guideline)

Tablica 2. Smjernice za upravljanje morskim područjem otoka Lokruma na temelju analiziranih radova kronološkim redom (smjernice za upravljanje – osmišljene na temelju opisanih aktivnosti, mjera, ciljeva i preporuka i pritisaka navedenih u analiziranim radovima; tip aktivnosti – definiran za svaku smjernicu za upravljanje)

Source	Activity / measure / goal/ recommendation mentioned in the paper	Potential threats mentioned in the paper	Management guidelines	Type of activity
Loebisch 1876 [54]	Defining physico-chemical properties of the sea water in the Dead Sea	/	Monitoring of chemical and physical properties in the Dead Sea	monitoring
König Von Habsburg Rudolf 1887 [48]	The island of Lokrum – a site for bird watching	/	Design and implement educational programmes for the different target groups of visitors	education / informing
	The area attracts the attention of ornithologists	/	Conducting scientific research and according to the results start bird monitoring	research / monitoring
Kronprinzessin Stephanie 1892 [50]	As special visitor attractions, coastal and marine motifs are mentioned; the Dead Sea, Arco naturale, caves	/	Design and implement educational programmes for the different target groups of visitors	education / informing
Baedeker 1891, 1896, 1900 [8,9,10]	The Dead Sea – one of the described motifs during the organised visit to the island	/	Design and implement educational programmes for the different target groups of visitors	education / informing
			Design and implement tour guide training programmes	education/ informing
Petermann 1900 [66]	The Dead Sea, Arco naturale – rocks and caves stressed as important objects of interest during the visit to Lokrum	/	Design and implement educational programmes for the different target groups of visitors	education / informing
			Design and implement tour guide training programmes	education / informing
Hirc 1905 [40]	The Dead Sea, rocks and caves described as objects of visitor interest as geomorphological phenomenon of biodiversity	/	Design and implement educational programmes for the different target groups of visitors	education / informing
			Design and implement tour guide training programmes	education / informing
Brusina 1907 [23]	A need to establish a zoological station in the vicinity of Dubrovnik	/	Improve cooperation with higher education institutions in establishing a scientific research centre	cooperation
Belamarić and Šerman 1989 [14]	A need for permanent monitoring of the benthic communities	/	Conducting scientific research and according to the results design and implement benthic monitoring	research / monitoring
Kršinić 1989 [51]	Need to include the Lokrum theme in the future permanent display of the Natural History Museum	/	Create a Lokrum natural history collection based on the ecological principles in the future Dubrovnik Natural History Museum	research / education
Špan et al. 1989 [75]	Insufficient data on the southern part of the Adriatic; need for a more comprehensive research of biocenosis	/	Conducting scientific research of marine biocenoses	research

Viličić 1989 [79]	Need to establish a science education station on Lokrum	/	Improve cooperation with higher education institutions in establishing a scientific research - education centre	cooperation
Meštrov 1989 [58]	Need to establish a science education station on Lokrum	/	Improve cooperation with higher education institutions in establishing a scientific research - education centre	cooperation
Šegulja and Tavčar 1989 [73]	Importance of field courses for biology students on Lokrum	/	Improve cooperation with higher education institutions in the implementation of field courses	cooperation / education
Katavić and Skaramuca 1989 [45]	Need to establish a science education station on Lokrum	/	Improve cooperation with higher education institutions in establishing a scientific research - education centre	cooperation
Kršinić and Gamulin 2001 [52]	Description of reasons for establishing institutionalized scientific research work on Lokrum in 1958	/	Improve cooperation with higher education institutions in establishing a scientific research-education centre	cooperation
Nuber et al. 2007 [64]	/	Occurrence of allochthonous algae *Caulerpa racemosa*	Regulate anchoring in the ecological network site and the buffer zone Establish monitoring of the invasive species Design and develop a database on introduced species	regulation monitoring research
Dobosz et al. 2008 [31]	/	Occurrence of allochthonous algae *Caulerpa racemosa*	Regulate anchoring in the ecological network site and the buffer zone Establish monitoring of the invasive species Design and develop a database on introduced species	regulation monitoring research
Đurđević Tomaš et al. 2010 [32]	/	Anchors ploughing under the sea bed, when two cruise ships collided at anchorage in the Lokrum canal	Regulate anchoring in the ecological network site and the buffer zone	regulation
Nikolić et al. 2010 [62]	Research of allochthonous red algae *Womersleyella setacea*	Occurrence of allochthonous algae *Womersleyella setacea*	Conduct scientific research Establish monitoring of the invasive algae species Design and develop a database on introduced species	research monitoring research
Biologika 2011 [16]	Need to create expert bases for the designation of a marine protected area of the island of Lokrum Establish monitoring of the invasive algae *Caulerpa racemosa* Establish monitoring of *Posidonia oceanica* sea beds Establish monitoring of coralligenous community Need to analyse effects of intensive cruising tourism and to perform cost benefit analysis	Occurrence of allochthonous algae *Caulerpa racemosa* and *Womersleyella setacea* Cruising tourism	Collect data and create expert bases for the designation of a marine protected area of the island of Lokrum Establish monitoring of the invasive algae species Design and develop a database on introduced species Start regular monitoring of the *Posidonia oceanic*a sea beds Establish monitoring of coralligenous community Research on environmental effects of cruising tourism and cost benefit analysis Regulate anchoring in the ecological network site and the buffer zone	research monitoring research monitoring monitoring research regulation
RAC/SPA - UNEP/ MAP, 2014 [68]	The Lokrum area has been assigned the mark of priority 1 out of 4 priorities regarding the necessity of monitoring the *Posidonia oceanica* sea beds	/	Start regular monitoring of the *Posidonia oceanic*a sea beds	monitoring
Mačić et al. 2014 [57]	/	Occurrence of two benthic allochthonous species in the Lokrum marine area	Conduct scientific research and according to the results define monitoring of allochthonous species Design and develop a database on introduced species	research / monitoring research
Carić et al. 2016 [27]	/	Sea water and sediment contamination caused by antifouling paint and heavy metals	Regulate anchoring in the *Posidonia oceanica* sea beds as well as in the buffer zone Conduct and support scientific research on marine pollution by ships	cooperation research

Crnčević and Bratoš Cetinić 2016 [28]	Establish natural science collections with the species from the Lokrum marine area	/	Design natural history collections for scientific research and education	research / education
	/	Marine debris	Undertaking marine debris removal from the Lokrum marine and coastal area	active management / research / monitoring / education / informing
Klautau et al. 2016 [46]	/	Occurrence of allochthonous sponge *Clathrina conifera* Klautau & Borojevic, 2001 in 2010	Conduct scientific research of allochthonous species and according to the results define monitoring Design and develop a database on introduced species	research / monitoring research

4. CONCLUSIONS / *Zaključci*

The protected areas, including the areas of the Natura 2000 ecological network, should provide a long-term preservation of endangered species and habitats. For each Natura 2000 site it is required to establish concrete site level conservation objectives and the necessary conservation measures to achieve those objectives. According to the Nature Protection Act, the Public Institution Lokrum Reserve manages the island of Lokrum but not its marine area which is part of the ecological network. Lokrum's natural values are an inseparable entity composed of land and sea. It is thus necessary to establish the management of marine part of the Natura 2000 site Lokrum in whole in order to ensure a more efficient protection as well as to plan the monitoring activities of the target habitat types, and in the long run, to undertake conservation measures. Bylaws to the Nature Protection Act are currently under preparation that should define the competencies of the public institutions managing both national protected areas and sites of the Natura 2000 ecological network. According to the proposal, the decisions on the authority for the management of the marine ecological network will be assigned to the corresponding public institutions for nature protection so the management of these areas will be more efficient.

Considering the expected redefining of the authority on the management of the marine area of the ecological network and the lack of continuous research and monitoring in the described areas, the guidelines based on historical data and natural-science research studies can contribute to the definition of conservation objectives, conservation measures and concrete activities to prevent the deterioration of coastal and marine habitats of the ecological network and to improve their status. Data gathered in this paper should be used in setting up the conservation objectives and measures for Natura 2000 site Lokrum. It is our conclusion that available data does not seem to permit to set these in a satisfactory way. This is confirmed with the fact that the majority of the proposed management guidelines recommend gathering additional data or establishing monitoring, rather than regulation or managing certain human activities. It is our recommendation that the new research should be focused towards providing reliable input for management decisions. However, due to the urgent need to address the existing threats to habitats, development of conservation measure should be done in parallel, because lack of data should not delay conservation of the site.

Therefore, the management guidelines and types of activities described in the paper can be a reliable base applied to various management documents and tools, and they primarily contribute to the development of the management plan for Lokrum with a special emphasis on the marine ecological network. The management plan is defined in accordance with the Nature Protection Act which determines the management and protection goals, the goal setting activities and the plan indicators. The recommendation is to take into consideration all the management guidelines defined on the basis of the analysed studies and to prioritise those with a special emphasis on research and monitoring. Certain guidelines have been repeated several times in thematically different studies covering the period of approximately hundred years. Such examples are natural history works which emphasises need to establish permanent scientific research, as well as educational programmes [23, 51, 79, 58, 73, 45, 52, 28]. Contemporary studies repeatedly underline the issue of introduced species, particularly invasive algae, as well as pressures to *Posidonia oceanica* meadows indicating necessity of adequate monitoring of sea bed habitats in Lokrum area [64, 31, 62, 57, 46, 32, 68, 27]. This confirms the requirement of following these guidelines to propose concrete measures in the management acts in order to manage the marine ecological network more efficiently in accordance with the legal requirements.

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